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Deep Structure Theory: An Introduction to a Unifying Theoretical Framework for the Analysis of Human Neuropsychology

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Cognitive neuropsychology research has tended to proliferate in domain-specific and theory-specific siloes without a common understanding of human nature and developmental change processes. This paper will introduce Deep Structure Theory (DST) as a new analytic paradigm that synthetically integrates and unifies across all human neurocognitive modalities, providing a framework for theoretical formalisms and corresponding empirical research throughout the cognitive sciences. The aim is to provide a standard model of neuropsychology grounded in the common mechanisms shared by all its faculties, thereby enabling the mind sciences to develop detailed and testable analyses in an iterative and integrated form rather than in lateral siloed domains of inquiry. After reviewing the epistemological and historical contexts from which DST has arisen, the deep structure algorithms will be described as the core mechanism of neuropsychology that constitutes the basic technical apparatus of the theory. Specifically, the algorithms describe the manner in which abstract mental information emerges as the product of compiled electromagnetic oscillatory activity, which is in turn contingent on the nature of complex neural circuitry systems. Together, DST forms a basis for unifying mental states with the rest of nature, including biology, chemistry, and quantum electrodynamics.

Keywords: Deep Structure Theory; dynamic complex systems; neurocognition; synthetic unified model

Introduction

Approaches to cognitive neuropsychology have so far not coalesced around an established understanding of human nature and its

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development; without consensus about the mechanisms by which the brain generates the mind, the operational systems of human development and information processing have remained obscure. The absence of a core body of validated principles, which is a common feature among pre-paradigmatic sciences (Kuhn, 1962), means that instead of maturing with vertical cumulative improvements, the fundamental mind sciences have expanded laterally within separate neurocognitive domains of interest, as well as within different theoretical and methodological traditions. This has produced rival symbolic, representational, processing, stochastic, domain-general, and domain-specific models of neurocognitive mechanisms (Frankish & Ramsey, 2012). A main contention of DST is that it integrates all such approaches into a synthetic unified model of the mind grounded in the functioning of the brain, thereby facilitating the mind sciences to develop detailed and testable analyses reflective of the integrated nature of neuropsychology.

The present paper will introduce Deep Structure Theory (DST), which is a set of algorithms and associated operations that aim to provide a theoretical framework for the analysis of abstract information structures generated by neural circuitry. These neuropsychological abstract information structures, which are called *deep structures*, are the emergent property of dynamic complex systems of neuronal circuits and functions. The neural networks produce electromagnetic oscillations of different types, the compiling of which appears to be the physical presentation of deep structures, and which constitute the multiplicity of computations across all the many domains of human perception, comprehension, and expression (Buzsáki & Vöröslakos, 2023; Desbordes et al., 2024; Greene et al., 2023; Martínez & Artiga, 2023; Smolensky, 2012). In short, the deep structural patterns associated with the organization of the brain are the fundamental nature of the human condition and, as such, systematic changes in their configuration over time constitutes developmental change. The remainder of the present paper will first discuss the epistemological and historical background in theory about mental states, and on which DST builds, synthesizes, and unifies. It will then briefly introduce the basic technical apparatus of DST and the relationship between deep structural computation and other natural biological and physical systems. As a novel theoretical framework, original stipulations are presented for the first time throughout this paper, and incorporated precursor ideas are acknowledged where appropriate.

Epistemology and Historical Background

Traditionally, there has been a divide between logical-positivist epistemologies on the one hand and constructivist ones on the other (Boxell & Marquis, 2022; Fricker et al., 2020). The former focuses on deductive and inductive reasoning via theory development and empirical hypothesis testing respectively, aiming to ascertain generalizable principles that describe nature. Meanwhile, the latter focuses on describing contextualized perceptions of reality as it is constructed through different cognitive and social conditions and lived experiences. While the two epistemologies have often been seen as conflicting and associated with different types of scholarship and stages in the development of intellectual inquiry, DST falls into an epistemological framework called *meta-modernism*. This essentially involves the integration of generalizable, empirically validated principles with the parameterization of those principles based on the unique contexts and experiences of the individual (Pipere & Mārtinsone, 2022).

The deep structural algorithms at the core of the DST paradigm result from universally innate principles governing the formation of neural networks and the associated emergent compiled electromagnetic neuropsychological information in the human neocortex. However, the algorithms themselves are empty abstract templates whose variables are expressed based on a combination of environmental stimuli and memorized experiences (i.e., previously encountered stimuli). Moreover, the algorithms include sequences of binary "switches" that are flipped one way or the other based on environmental input (Chomsky, 1981). In short, the deep structural algorithms offer a response to the conjecture of Wilson (1990) in which it is suggested that biology must have some means by which to sort through the multitude of environmental signals to produce the perceptual "reality tunnels" of the individual: namely, the universal deep structural algorithms of the neocortex are adapted by the signals from the environment to construct unique mental information structures based on the experiences of the individual.

DST is an extension of a wide range of prior developments in mental state theory encompassing logical-positivist and constructivist epistemologies, responding to the need for an analytical framework that can synthesize a meta-modernist integration. Since antiquity, philosophers have discussed the relationship between matter and mental states, with Aristotle being perhaps the first to suggest that former was a material basis for the latter (Polansky, 2007), in contrast to dualist accounts posited by Plato and later Descartes (Kind, 2020). Enlightenment philosopher John Locke refined the discussion by pointing out how it is not possible simply through introspection alone to determine whether thought is part of matter itself, or some type of immaterial phenomenon that is attached to matter. He went further, suggesting that in the absence of an understanding of the relationship between matter and mental states, it might be that mental states emerge from some "substance" other than matter (Locke, 1690). Locke described the emergence of a faculty for thinking from underlying substances as *superaddition*, which foreshadowed the later development of complex systems theory and its application to neuroscience and quantum electrodynamics.

Complex systems theory is a framework for modeling the interactions, transactions, and dependencies that exist between the self-organizing constituent units that make up a dynamic adaptive system (Fuchs, 2013). The self-organization, or so-called *spontaneous order*, of the units appears as a result of information transmitted between and within the units of the system. In the case of DST, the expression and inhibition of genes provides an overall template for neural structures and functions but the range of specific synaptic connectivities depends on neuronal transmission over time, which is itself sensitive to environmental stimuli (Marcus, 2004; Toga & Thompson, 2005). Moreover, the focus of DST is to describe the interactive and self-ordering mechanisms for the abstract information units that emerge from this underlying neural activity.

Relationships between the constituent units of a complex system produce *emergence*, which is where new properties that the individual constituents do not possess on their own are brought into existence by their interplay (Fuchs, 2013). Oftentimes, these emergent phenomena require a whole new level of ontological analysis, producing the hierarchy of reality that runs from the subatomic to the atomic, and on to the molecular, cellular, and biological systems through whole civilizations and cultures, ecosystems, and even the universe itself (Graben & Atmanspacher, 2006). Ultimately, all entities in nature are complex systems while also being part of larger complex systems and containing sub-parts that are themselves complex systems. In the case of the brain, compiled electromagnetic oscillations are the emergent property of interactions among billions of neurons and trillions of dynamic and adaptive synaptic connections that form assorted and changeable neuronal network configurations (Buzsáki & Vöröslakos, 2023; Greene et al., 2023; Martínez & Artiga, 2023; Smolensky, 2012; Westermann et al., 2010). The contention of DST is that these emergent oscillations *are* neuropsychological deep structures; i.e., the faculty for mental states, akin to Locke's notion of superaddition. It should also be noted that internal dendritic activity within individual neuronal cells has its own computational capacity that might contribute to the deep structures (Gidon et al., 2020), potentially interacting with computation related to wider neurochemical synaptic transmission (Gershman, 2023).

In addition to emergence, the interaction of units in complex systems also typically produces *nonlinearity*, which refers to the output of the complex system being non-proportional to changes in the input (Fuchs, 2013). Often discussed as the Poverty of the Stimulus, or Plato's Problem, it has long been known that human mental states are generative, meaning the outputs that they generate are not limited to the tokens of input to which the brain has been exposed in the environment (Chomsky, 1981). Instead, neural networks use the innate deep structural algorithms to re-organize constituent units extracted from the input, while adding others from memory stores or removing them, so as to produce entirely novel emergent outputs in the form of compiled electromagnetic oscillations (Buzsáki & Vöröslakos, 2023; Greene et al., 2023; Martínez & Artiga, 2023; Smolensky, 2012). This is, in essence, the nature of the human capacity for innovative thought and creativity.

While the innate deep structural algorithms in DST are abstract templates whose variables are extracted from the environment and memory, the algorithms themselves are recursive. *Recursion* means that the algorithm refers to back into itself, such that it can, in principle, be reapplied over environmental variables infinitely (Chomsky, 1981, 1995). In other words, the possibility for integrating units of information into a deep structure is unbounded such that there is an infinite array of possible deep structural outputs. As a simple illustration, one can always integrate additional modifiers into a basic unitary concept such as *the [very very very extremely big, red, weirdly-shaped] apple*, with each modifier altering the overall meaning of the concept. The fact that meaning is the product of the computation of constituent units was codified in the Principle of Compositionality in formal philosophy (Boole, 1854; Frege, 1884, 1963), with the link between recursion and meaning first established by Peirce (1865).

Furthermore, nonlinearity—as it appears in the DST algorithms—is an example of what the philosopher Wilhelm von Humboldt called the *infinite use of finite means*, which is found in all algorithms governing digital systems (von Humboldt & Buschmann, 1836). For example, using the "finite means" of an algorithm to add unit after unit to the seconds, minutes, and hours counts, plus the environmental input variable of numerals 0-9, a stopwatch would produce infinitely combinatorial novel outputs; given the Principle of Compositionality, this entails infinite possible meanings for the time as recorded by the stopwatch. Just as there would be practical constraints on the application of the algorithm, such as screen size or energy supply, there are processing resource constraints that apply over computation in neural networks, such as working memory and executive function. However, note that these processing limitations are constraints on the practical *use* of the algorithmic deep structure system in real time while the DST algorithms are the nature and the constraints of the computational system itself. This is notwithstanding that processing factors necessarily impact deep structures as they emerge, which will be discussed below. As von Humboldt and Buschmann (1836) similarly noted, the explanatory power of a rules-based system comes from the inherent finite constraints it offers such that it can, in principle, parse unbounded data while (re-)arranging it as a sense-making faculty. In other words, it is precisely the maximally constraining nature of the finite deep structural algorithms that enables mental states to represent the full diversity of signals that constitute the totality of the human experience.

The nonlinearity produced by the DST algorithms can cause over-generation of deep structures, especially in childhood and adolescent development and in the development of most psychopathologies (Haywood et al., 2021; Taylor, 2005). In such cases, deep structures have fewer constrained characteristics, producing non-real outputs such as nonce words, visual hallucinations, or distorted beliefs. However, the application of the algorithms adapts over time based on the ambient cultural stimuli through the successive processes of trial-and-error mapping of deep structures with their intended contextual consequences and contingent feedback loops (Gleitman & Trueswell, 2020). *Feedback loops*, in complex systems theory, refer to when the outputs of the system, and the consequences of those outputs, affect the subsequent structuring of the system; they are the essence of how complex systems learn (Fuchs, 2013). Psychotherapy, for example, attempts to create feedback loops to facilitate transformations of deep structures from those that are pathological into their antidote equivalents (Boxell, 2025).

Throughout the life-course, successive feedback loops over time result in the dynamic restructuring of neural networks to change the range of possible deep structures that emerge. Likewise, neurodevelopmental predeterminants, neurodegeneration, brain damage, or chemical exposures will result in shifts in the nature of the possible deep structures (Bánréti et al., 2016; Bates et al., 1995; Carhart-Harris et al., 2013; Clahsen, 2008). In other words, DST provides a framework for describing human nature and its development at the level of the genetically predetermined algorithms, in terms of shifts in their application that are based on the feedback loops obtained from the environmental stimuli.

While DST allows for a granular description of developmental change, the history of human development theory includes many stage-based models based on the interaction of biological maturation and the environment. The Enlightenment philosopher Jean-Jacques Rousseau described the three stages of infancy, childhood, and adolescence in his novel *Emile*, and explicitly relates these to biological maturation and its interactions with the environment (Rousseau, 1979). Likewise, Freud (1949) associated his stage-based psychosexual model of development with biological maturation. While many details are not falsifiable or are inconsistent with empirical findings (Beck & Hurvich, 1959; Dell, 1995), perhaps Freud's biggest contribution was the very notion that much of the information processing that occurs is unconscious—a proposal that is consistent with DST and modern neurobiological results (Kang et al., 2017; Schurger et al., 2021; Soon et al., 2008). Likewise, the distinction between the id, the ego, and the superego *broadly* corresponds to the following: instinctual limbic responses and their integration throughout biological systems; neocortical deep structural processing and its integration throughout neuropsychology and biology; and metacognition in which mental states become self-aware, constituting a "self" (Christoff et al., 2011; Phillips, 2023). Neocortical deep structures include a re-rendering of instinctual or emotional information transmitted from the limbic system, which also implies some consistency with Freud's drive theories (Kraljević et al., 2021; Kross et al., 2011; Ledoux, 1996; Sousa, 2016).

It is interesting that Freud essentially predicted a theory such as DST, in which abstract information emerges from neural structure, in stating that "all of our provisional ideas in psychology will presumably one day be based on an organic substructure," (Freud, 1914, p.78). Similarly, in observing that there are trends in the archetypal fantasies that humans experience across cultural contexts, Freud (1933) suggested that an evolutionary endowment is responsible. Carl Jung further developed this idea with his theory of innate archetypes that suggested there is a universal unconscious substructure that is responsible for the common order found in human thought, affect, behavior, and culture. These archetypes, including representations for specific events, relationships, motifs, the self, and others, are viewed as templates to be adapted by the specific details of context as observed in stories, dreams, religions, politics, art, and so forth (Jung, 1952). Several other psychoanalytic theorists, including Melanie Klein, Jacques Lacan, and Robert Langs, also developed the idea of innate archetypes built into the structure of the unconscious (Samuels, 1986). In DST, the genetic endowment for the deep structural algorithms provides universal constraints in how information extracted from the environment and memory may be represented, predicting generalizable patterns of mental development and activity. Indeed, Lacan went further than the other psychoanalysts in suggesting that the unconscious has an innate structure determined by symbolic ordering of the archetypes in relation to lived experience, bringing him even closer to the postulates of DST itself.

Jean-Jacques Piaget, influenced by the psychoanalytic idea of an endowed mechanism for structuring information in mental states and yet unconvinced by the Freudian psychosexual model, proposed his own stage-based theory (Piaget, 1952). While the stages themselves and their limitations need not concern us here, the mechanisms Piaget proposes by which children internalize information reflect the feedback loops of the underlying complex neuropsychological system. Namely, his model describes cycles of *assimilation* and *accommodation*, where the former refers to incoming environmental stimuli that is integrated into compatible mental schemas, and the latter refers to incoming environmental stimuli that creates disequilibrium with incompatible mental schemas, resulting in their eventual transformation. The Piagetian notion of *schema* is essentially analogous to deep structure; while DST fills in a lot of the specific detail about the algorithmic nature of the schemas that Piaget did not specify, his theory offers a rudimentary description of how deep structure interacts with environmental stimuli to produce developmental change over time.

Micheal Mahoney further expanded on this conception of mental change with his *cognitive constructivism*, focusing on how internal representation is constructed based on ambient stimuli (Mahoney, 1974). He paid particular attention to mental development induced in psychotherapy (Mahoney, 2006); notably, he equates assimilation and accommodation to cycles of order, disorder, and re-ordering of mental representation and resulting behaviors and interpersonal relationships. Other neo-Piagetian researchers have translated these mechanisms for deep structural change into their underlying neurobiology (Westermann et al., 2010). The resulting *neuro-constructivist* framework describes the feedback loops by which environmental stimuli affect the complex system of underlying neural networks. Where incoming data assimilates into the neural order, neural activity will strengthen the compatible network. This is achieved as existing synaptic connections are activated, while new neural connections and new neurons, technically known as *synaptogenesis* and *neurogenesis* respectively, further enforce the network or create whole new circuits that accommodate new deep structures. Meanwhile, synaptic connections are pruned, and neural atrophy or death may occur, when the environmental stimulus no longer activates the relevant network connections.

Neuro-constructivist mechanisms permit the environment to shape specific neural network connectivity, and restructuring occurs within the overall template of global and local brain structure that is determined with a combination of genetic predetermination (Toga & Thompson, 2005), gene expression or suppression among different environments (Arden, 2019; Roth, 2012; Seung, 2012; Westermann et al., 2010), and pattern-forming molecular codes (Hassan & Hiesinger, 2015). Like its Piagetian forebears, neuro-constructivism has, however, not clarified the nature of the neuropsychological representation that is emergently computed from its processes (Favela & Machery, 2023). This is a gap that DST intends to fill in-line with the established neurobiological base (Kazanina & Poeppel, 2023).

At the intersection of neuro-constructivism and complex systems theory is the discipline of *connectonomics* (Munsell et al., 2018; Seung, 2012). Connectonomics is concerned with the study of the *connectome*, which is the mapping of neural circuits, and the traits of human nature that result from the reweighting, reconnection, rewiring, and regeneration of neurons, synaptic connections, and the different types of electrochemical activity involved within and between neurons. The task of mapping connectomes is formidably challenging, with even simple lifeforms like *C. elegens*, a worm with only 300 neurons and 7000 connections, taking around 12 years to map entirely (Seung, 2012). The connectome of *C. elegens*, in common with most non-mammalian lifeforms, is entirely genetically determined and therefore universal across the species, producing pre-specified information processing and behavioral outputs in all individuals. However, among some—mostly mammalian—species, the capacity for learning and change evolved. This means the connectome evolved the mechanisms to change in real-time to accommodate new incoming environmental stimuli. Mapping a human connectome is complex, therefore, not only because it consists of 86-100 billion neurons that can fire at multiple different amplitudes across as many as a quadrillion synaptic connections (Krebs et al., 2017), but also because it is always something of a "moving target." That said, the task is aided by the constraints provided by the overall genetic template (Toga & Thompson, 2005), the range of possible epigenetic expressions (Arden, 2019; del Val et al., 2024), and the probabilistic nature of the neurons firing and forming synaptic connections (Tervo-Clemmens et al., 2023; Westermann et al., 2010).

In view of this, genomics, probability theory, and cellular-level real-time neuroimaging techniques are being brought to bear on the challenges of human connectonomics (Munsell et al., 2018; Vogel et al., 2023; Walsh et al., 2021; Wilcox & Barbey, 2023). The result is the arrival of connectome mapping methodologies like *probabilistic tractography* that can already map small subsets of neural tissue and may be able to provide real-time maps of larger sections (Chang et al., 2023), and eventually even the whole brain (Seung, 2012; Wilcox & Barbey, 2023). One limitation of connectonomics is that it relates neural connectivity directly with human traits without considering the nature of the signals encoded in the electromagnetic oscillations that emerge from the neural activity (Buzsáki & Vöröslakos, 2023; Greene et al., 2023; Martínez & Artiga, 2023; Smolensky, 2012). Nonetheless, the implications of complex systems theory and neuro-constructivism suggest that this emergent deep structural property of the connectome is key, as has been previously implied (Dennett, 1991; Minsky, 1986).

This notwithstanding, there have been numerous previous attempts to describe the nature of deep structure in cognitive science. Herbert (1962) observed how hierarchies of constituent units of information inherently arise as a constraint on computational efficiency; units within complex systems do not naturally organize into linear strings, but instead into hierarchical three-dimensional webs of connections (Polanco & Newman, 2023). Moreover, Herbert (1962) established how recursive algorithms produce such a hierarchical tree structure, and as discussed earlier, the deep structural algorithms must be recursive to account for the nonlinearity—i.e., the generative, creative outputs—in the neuropsychological complex system (Dedhe et al., 2023). Indeed, there have been attempts to characterize the nature of deep structures for many different human neurocognitive modalities such as: language (Chomsky et al., 2023; Jackendoff, 2006; Kempson, 1977; Chomsky, 1995; Seuren, 2017); music (Fitch, 2013; Lerdahl & Jackendoff, 1983; Poulin-Charronnat et al., 2005; Rohrmeier & Pearce, 2018); vision (Marr & Poggio, 1976); pictures and other expressive art (Cohn, 2020); mathematics (Heller, 2018; Pozniak et al., 2018; Scheepers & Sturt, 2014); and emotional states (Hsieh & Sharma, 2019; Lohse & Overgaard, 2019). Minsky (1980) also proposed a theory of memory traces called *k(nowledge)-lines* that relies on spreading neural activation as determined by hierarchical deep structures.

Arguably the most prolific set of deep structural theories was produced by Noam Chomsky, whose focus was on describing the nature of the language system. He named the deep structural language system *Universal Grammar* (UG), although the idea of UG itself originates with Peirce (1865). Chomsky was the first, however, to express the deep structural algorithms and how variables within the universal innate algorithms can be set by environmental stimuli (Chomsky, 1957, 1981). He later refined his initial formal theory, called *Transformational Grammar*, numerous times to improve its explanatory adequacy. One such refinement was *X-bar Theory* (Chomsky, 1970, 1986), which introduced three specific algorithms to account for different structural relationships that are possible between linguistic units. Another, called the *Minimalist Program* (Chomsky et al., 2023; Marcolli et al., 2023; Chomsky, 1995), attempted to reduce the complexity of stipulations about the algorithms and the constraints that apply to them for computational elegance and efficiency.

Chomsky (1957) was also the first to use the term *deep structures* to describe the mental representations of language that his algorithms produced, although this was likely based on Charles Hockett's notion of *deep grammar* (Hockett, 1948). *Deep* refers to the fact that the mental structure being described is unconscious and can be "spelled-out" into different surface structures by re-organizing a shared underlying deep structure, such that the sentence *Jim painted the doghouse* and the sentence *the doghouse was painted by Jim* can be generated through different arrangements of a common deep structure, for example.

Formal linguistics has subsequently produced ever-more detailed and sophisticated accounts of linguistic deep structures. However, the Chomskyan theories assume that deep structure and language are one and the same, and therefore that the system for thought or complex information computation is essentially linguistic; indeed, Hauser et al. (2002) suggests that the language system initially evolved not for communication but for internal thought. This conflation of language and abstract thought likely arose because grammatical encoding offers a more granular imprint of the underlying combinatorial meaning than other neurocognitive modalities (e.g., consider the subtle meaning difference created by grammatical aspect in the contrast between *the cat was sat on the mat* versus *the cat was sitting on the mat*). While the core algorithms proposed below for DST are modeled after Chomsky's X-bar approach (1970, 1986), and several key constraints are modeled after the Minimalist tradition (Chomsky, 1995; Chomsky et al., 2023), DST as proposed in the present paper makes a radical departure from the Chomskyan approach in suggesting that the algorithms are *not*, in fact, linguistic at all but are central to all human neuropsychology. Indeed, it has been empirically shown that the recursive algorithm applies domain-generally (Dedhe et al., 2023; Herbert, 1962).

Alternative models of linguistic deep structure from the cognitive linguistics tradition have postulated that semantic deep structures can be transformed into syntactic ones (Jackendoff, 2006; Kempson, 1977; Seuren, 2017). While there is similarity between such approaches and the DST formulation in that both allow for a transformation from meaning structure to a re-rendered syntactic form, DST differs from cognitive linguistics approaches because, in common with Chomskyan theory, it accepts that there are also many features of meaning in language for which syntax must *first* be computed. More fundamentally, DST proposes that there are two sources of meaning in deep structural computations: the compositionality of the underlying modality-independent conceptual structure, and the compositionality of modality-dependent deep structure. As an account of the whole mind rather than only language, DST differs from both generative and cognitive linguistics in that conceptual structure need not spell-out into language at all but could also appear as one of many other neurocognitive modalities. Given that DST allows for features of a modality-specific computation to influence the modality-independent conceptual structure, as well as the reverse, it is also simultaneously compatible with empirical findings in both generative and cognitive linguistics (Boxell, 2016). In sum, as a general neuropsychological model, DST integrates across different approaches to formal linguistics; moreover, it extends them to an even deeper conceptual deep structure on the one hand, and to the other neurocognitive modalities on the other, to build a unified model of the whole human mind.

DST postulates that its algorithms produce modality-independent conceptual deep structure called the *I(nformation)-Phase* that can then be re-rendered into one of several different neurocognitive modalities in *S(pellout)-Phase* deep structures. These S-Phase deep structures include language, mathematics, music, pictures, expressive arts, and sophisticated visuospatial and sensorimotor activity such as dance. This model accounts for superficially different modalities that are all able to express symbolically the same essential structural relationships among their constituents and consequently can prime neural activation in one another (Kutta et al., 2017; Lohse & Overgaard, 2019; Patrick et al., 2023; Poulin-Charronnat et al., 2005; Scheepers & Sturt, 2014), not to mention their shared common underlying I-Phase meaning. It is also instructive to note that all the S-Phase modalities are uniquely human and arose around the same time in the evolutionary record, indicating that they are part of the same system (Heyes & Huber, 2000). Meanwhile, it seems that the deeper I-Phase conceptual capacity evolved earlier and thus is not uniquely human but is broadly mammalian (Boxell, 2016). At the root of the DST account, heavily entrenched k-line trees for the modality-independent I-Phase conceptual structures also account for personality traits, resulting interpersonal relationship dynamics, and the ability to receive and incorporate emotional signals from the limbic system into thought (Christoff et al., 2011; Kraljević et al., 2021; Ledoux, 1996; Sousa, 2016). Highly linked I-Phase structures produce capacities for a projected "theory-of-mind" for other individuals and contingent empathy and morality. There is an interesting echo, here, of the tripartite id, ego, and superego of the Freudian model (Freud, 1949).

In sum, DST applies the principles of complex systems theory, neuro-constructivism, and connectonomics to provide a framework for the analysis of compiled electromagnetic oscillations that emerge from neural activity as a signal encoding abstract information. This shift in ontological levels between neural structure and mental states provides a means to account for the facets of human nature and their development over time. Table 1 provides a summary of the features across different theoretical paradigms compared with DST and shows that DST most comprehensively unifies the other approaches.

Table 1

Comparison of Theory Features

Theory Feature	**DST**	DCS	GC	NC	Con.	Gen.	X-bar	M	CL	Ma	I	Mu	S/V	Me	Pa
Hierarchical branching nodes	**X**	X	X				X	X	X	X	X	X	X	X	
Recursive algorithms	**X**	X	X				X	X	X	X	X	X	X	X	
Real-time processing compatibility	**X**	X	X	X	X	X	X		X	X	X	X	X	X	
Development-al change	**X**	X		X	X	X	X	X	X						X
Emergent electromagnet-ism	**X**	X					X								
Neural circuitry	**X**	X		X	X	X									
QFT isomorphism	**X**						X	X							
Modality-independent meaning	**X**		X	X		X								X	X
Integrated cross-modality effects	**X**	X	X	X	X	X			X					X	X
Language-specific effects	**X**				X	X	X	X							
Mathematics-specific effects	**X**				X	X				X					
Image-specific effects	**X**				X	X					X				
Music-specific effects	**X**				X	X						X			
Sensori-motor and/or visuo-spatial specific effects	**X**				X	X							X		
Interpersonal-emotional effects	**X**	X			X	X									X
Memory encoding and retrieval effects	**X**				X	X								X	X

Note: DST = Deep Structure Theory; DCS = Dynamic Complex Systems Theory; GC = General Computational Theory; NC = Neuro-constructivism (Neo=Piagetian Theory); Con. = Connectonomics (Neural Circuitry); Gen. = Genomics; X-bar = X-bar Theory (Chomskyan Linguistic Deep Structure); M = Minimalist Theory (Chomskyan Linguistic Deep Structure); CL = Cognitive Linguistics; Ma = Mathematical Deep Structure Theories; I = Image Deep

Structure Theories; Mu = Music Deep Structure Theories; S/V = Sensorimotor and Visuospatial Deep Structure Theories; Me = Memory Deep Structure Theories; Pa = Psychoanalytic Theories

The Technical Apparatus of Deep Structure Theory

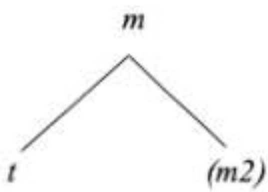
While it is beyond the scope of the present paper to give a detailed exposition of DST, what follows is its core theoretical base involving three algorithms, modeled after Chomsky (1970, 1986). In each of the algorithms, the terms to the right of an arrow are *sister nodes*, and can *switch* order based on environmental stimuli, while the node to the left of the arrow is "projected" by one or both terms on the right such that it inherits the information from its *daughter(s)*. The variables *m*, *i*, and *t* represent *maximal node*, *intermediate node*, and *terminal node* respectively. Nodes are abstract *variables*, the exact value of which is to be inducted by either the environmental stimulus or activation of part or all of a stored "k-line" deep structure, similar to Minsky (1980) and introduced below. In terms of development, the deep structural algorithms are generally underwritten by a type of neuroplasticity that enables them to remain open to inputting new variable nodes throughout the life-course; as such, constant change related to the variable nodes is possible, particularly in the I-Phase. That said, many switches within the S-Phase relate to neuroplasticity that passes through *sensitive periods* during childhood, after which their parameters become set to those of the ambient surroundings (Taylor, 2005). Learning new S-Phase parameters is a matter of passive accommodation before such a sensitive period but typically requires conscious metacognitive learning thereafter; consider language learning before and after puberty as an obvious example (Taylor, 2005).

The first algorithm to be discussed is called the *complement algorithm*, and is as follows:

(1) *Complement Algorithm:* $m \leftarrow t\ (m_n)$
a maximal node (m) is projected by a terminal node (t), which may in turn optionally have another maximal node (m_n) *as its sister*

A terminal node (*t*) is a unit of information that is being integrated into the deep structure. This algorithm states that each terminal node (*t*) projects a maximal node (*m*) and can optionally have a new maximal projection (m_2) as its sister. Should a new maximal node (m_2) be integrated, this algorithm means that (m_2) will itself be projected by its own terminal node (t_2); in turn, (t_2) would also optionally be able to take a further maximal node as its sister (m_3), and so on *ad infinitum*. This self-reference of the algorithm back to itself produces recursion, making the potential application of the algorithm unbounded. Note that the complement algorithm has *primacy* over the other algorithms, meaning that every maximal node *must* be projected by a terminal node in all deep structures. Recall that Herbert (1962) and Polanco and Newman (2023) discuss how recursion, nonlinearity, and hierarchical structure are all bound together in complex systems, and as such the deep structural algorithms do not describe linear strings so much as hierarchical three-dimensional webs of connecting node trees; the complement rule in (1) is therefore more appropriately represented as (2). The dynamic switch parameters of the daughter nodes in these algorithms means that points where the branches meet in the web should be seen as a "hinge" on which the structure can turn to change its ordering and assimilate or accommodate incoming data during development and learning.

(2)

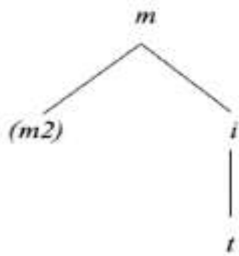


Relative to its counterparts, one variable can become the focus of its deep structure; that is, it has a more salient role to play in *specifying* the information in a structure, which affects the way the structure is computed (Chomsky, 1986). These units are called *specifiers* and activate the *specifier algorithm.* For example, the agents of actions are typically specifiers, such that in the deep structure associated with *the girl screamed*, the part deriving *the girl* is structurally more important than the part for *screamed*. The meaning of *screamed* can only be fully realized when the meaning for *the girl* is also understood because *the girl* performs the screaming and so the nature of the screaming is contingent on her nature, too; meanwhile, the meaning for *the girl* is not contingent on the nature of whatever she happens to be doing. This algorithm says that an intermediate node (*i*) is added that projects a maximal node (*m*) and takes a new maximal node (*m2*) as its sister; it is this new maximal node (*m2*) that functions as the specifier. Note that since the complement algorithm above states that every maximal node is projected by a terminal node, and it has primacy over the specifier algorithm, the insertion of an intermediate node means that there must still be a terminal node (*t*) beneath it projecting the initial maximal node, as well as terminal nodes under the new maximal projection (*m2*). Applying the example to (4), *the girl* would arise from terminal nodes (*t*) that project (*m2*) and *screamed* would be the (*t*) node shown.

(3) *Specifier Algorithm: m* ← *(m2) i*

a maximal node (m) may be projected by an intermediate node (i) that has another maximal node (m2) as its sister

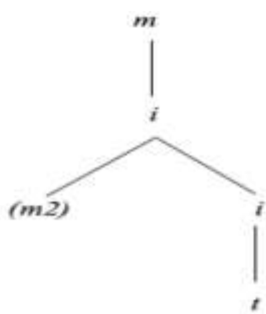
(4)



The final algorithm to be discussed is called the *adjunct algorithm* and is used to integrate constituents, called *adjuncts*, that are more weakly branch-attached to the deep structure than others.

(5) *Adjunct Algorithm: i ← i (m2)*
an intermediate node (i) may be projected by a copy of itself (i), the latter of which is required to have a maximal node (m2) as its sister

(6)



The sister node of the double-intermediate projection is the adjunct constituent, namely (*m2*) in (6). To illustrate an adjunct constituent, consider the following four sentences that have spelled-out a shared underlying I-Phase deep structure into different linguistic S-Phase ones:

(7) I gave the gift on Tuesday during the storm.
(8) *I gave on Tuesday the gift during the storm.
(9) *I gave during the storm the gift on Tuesday.
(10) I gave the gift during the storm on Tuesday.

Items (7) and (10) show it is possible for *during the storm* and *on Tuesday* to switch places, but (8) and (9) show it is not possible for *the gift* to switch places with either *on Tuesday* or *during the storm*. The reason is that *the gift* is conceptually more strongly branch-attached as a complement to the act of giving than are either *on Tuesday* or *during the storm*. These latter two constituents are adjuncts in the underlying I-Phase deep structure because they add peripheral modifying information to the core concept of "me giving the gift," and such differences in the structural relationships of the I-Phase constrain the possible organizations that spell-out in the S-Phase, in this case for language.

Indeed, DST postulates that its algorithms apply across multiple layers of computation within the structure of the mind. Initially, they generate the I-Phase computations, which generate pure conceptual information structures; however, these structures may undergo *phase transition*, meaning that they are re-rendered into the S-Phase computations that reformats them with *adornment features* to specify the structures for one of several modalities, such as language, mathematics, music, images, visuospatial and sensorimotor activity, and so on.

K-Lines

Deep structural webs of branching node trees are not only fundamental to recursive computation in the dynamic complex system of the mind (Dedhe et al., 2023; Herbert, 1962; Polanco & Newman, 2023), they also serve as the memory mechanism. As a node is added, an excitatory branch-attachment is made with all the other nodes that are simultaneously active; the branch becomes part of a *k(nowledge)-line* (Minsky, 1980). Executive functioning enables spreading activation across k-lines, producing neighborhood and stochastic memory effects well-known in the basic memory literature (Siew, 2019), and are determined by the *recency*, *saliency*, and *frequency* of the branch-attachments that make up a k-line deep structural tree. Notably, this approach integrates the emergent creativity of deep structural computations with the statistical effects of lived experience in the environment (Chen et al., 2023).

Furthermore, k-line strength determines the co-activation of nodes across a k-line tree when one of its components activate; while one node might precipitate some entire deep structures to be retrieved, others may co-activate only local neighbor nodes in their k-line tree to a moderate or mild extent. Together, this produces quantifiable *contextual prediction* effects for likely upcoming nodes. Given that k-line deep structures are recurrent patterns of compiled electromagnetic oscillations, they neurobiologically downregulate neural circuits via molecular potentiation (Hassan & Hiesinger, 2015). Circuitry strength and associated electrical output are thus measurably associated with memorized information (Castello-Waldow et al., 2020; Franklin & Grossberg, 2017; Gershman, 2023; Perich et al., 2020). Individual adjustments to a k-line deep structure constitute a token of memory consolidation, and such tokens accumulate into developmental change pathways across the life-course (Klinzing et al., 2019; Pronier et al., 2023).

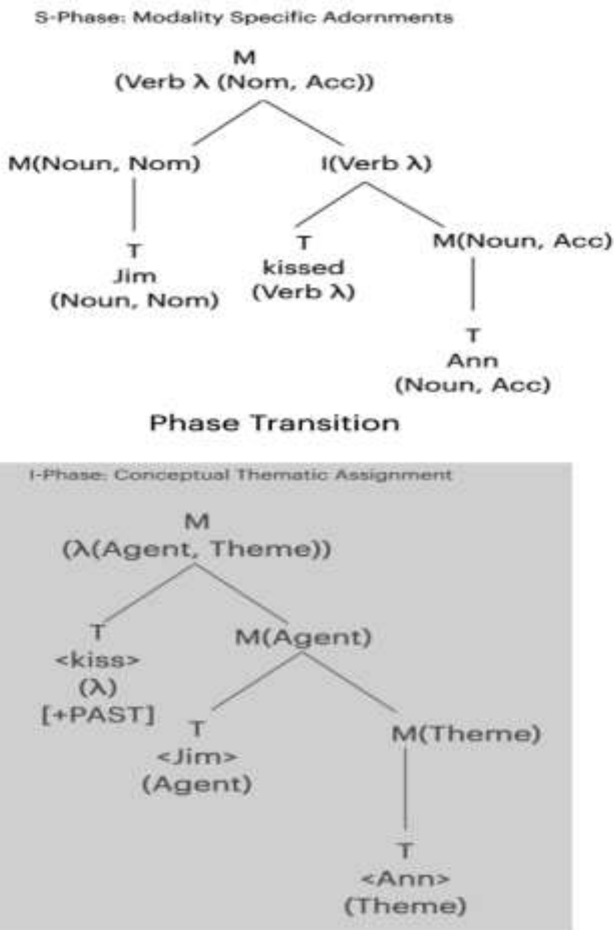


Figure 1: Example I-Phase and S-Phase Deep Structural Derivation

I-Phase

For the sake of illustrative exposition, Figure 1 provides an oversimplified deep structural derivation for the I-Phase concept of an individual called Jim having kissed an individual called Ann in the past and spells it out into the linguistic S-Phase form *Jim kissed Ann.* Note, however, that in reality there are many more computational phenomena at work in deriving such a representation than are shown here. In the I-Phase, the highest maximal parent node, called the *root node*, is projecting a function (λ). In this case, it is an *action process* that takes two conceptual variables, an *agent* and a *theme* (λ(agent, theme)); such variables are called *thematic assignments*, referring to the roles they play in the conceptual structure (Haiden, 2005). In this example, there is an agent, which is an entity that will do the action, and a theme, which is the entity upon which the action is done. The terminal node projecting the root node is the action function (λ) itself, <kiss>. Note that < > indicates the language-independent conceptual meaning, and not any arbitrary S-Phase sign—in this case, a word—that might provide reference to it (de Saussure, 1966).

Note also that while the present analysis assumes unitary “word-level” concepts as terminal nodes for exposition, given they have unique neural signatures that integrate into neural signatures for larger information structures (Desbordes et al., 2024; Graves et al., 2016), it is likely that each terminal node decomposes further into “nano-deep-structural” derivations with smaller conceptual features serving as terminal nodes (Taraldsen, 2019). It is not known, however, how many layers of further compositional derivation there might be within the complex system of deep structure, although simple unitary concepts are likely built with the same essential mechanisms as the complex “sentence-level” propositions. Indeed, the components of conceptual thematic assignment variables induce structural priming effects akin to those mentioned earlier for higher-order deep structures (Ziegler & Snedeker, 2018).

Information between squared brackets [ ] is a conceptual feature, and so [+PAST] indicates the function <kiss> is conceptually marked as having occurred in the past. The remainder of the I-Phase must integrate the variables to satisfy the function <kiss> as projected onto the root node, (λ(agent, theme)). As such, the sister for <kiss> is the maximal node for the (agent) variable, which is projected by <Jim>, and in turn takes as its sister the maximal node for the (theme) variable, projected by <Ann>. Overall, this I-Phase encodes the abstract meaning that there is an action specified by the function <kiss> that is done by <Jim> to <Ann> in the past. Note that the geometry of the branching nodes precisely describes the combinatorial meaning of the deep structure in line with the Principle of Compositionality (Boole, 1854; Frege, 1884, 1963), and so any re-organization of the branching will produce new meaning. For example, the concept <The student saw the teacher from the classroom> might be derived with <from the classroom> integrating as a complement constituent to <the teacher>, meaning the teacher, who was seen, is from the classroom. Alternatively, <from the classroom> might branch-attach as an adjunct constituent to <saw the teacher>, meaning the act of seeing the teacher was done by the student from the classroom.

Moreover, the I-Phase has integrated the mechanics of predicate calculus that have long been used to compute propositional denotations (i.e., *who* or *what* did *what* to *what* or *whom* with adjunctive *how* and *why* information) and appears to be fundamental in neuro-symbolic oscillatory representation (Kazanina & Poeppel, 2023; Whitehead & Russell, 1910). Here, it is applied over theta-theoretic concept-role variables and embedded into the hierarchical branching node webs to maintain parsimony with the computational mechanisms of complex systems (Dedhe et al., 2023; Haiden, 2005; Herbert, 1962; Polanco & Newman, 2023).

S-Phase

After meaning is computed in the I-Phase, it can undergo *phase transition*. For exposition, in Figure 1 it is assumed that the concept denoted in the I-Phase is to be spelled-out into language in the S-Phase, but it just as easily could have been some other S-Phase modality such as a picture. Furthermore, for simplicity Figure 1 does not show that all I-Phase specifications remain present in the S-Phase exactly as they had been in the I-Phase but as silent trace-copies. S-Phase features, known as *adornment features*, provide specification for the use of the deep structure within the specific modality in question. In Figure 1, the node <kiss> has now transformed into *kissed* during the phase transition into the linguistic S-Phase, which occurs because this is the word whose meaning and grammatical morphology denotes the concept <kiss> [+PAST]. Note that this node is adorned with the label (Verb λ), specifying the grammatical role that the word possesses, and maintaining its I-Phase role as a process function. The *Extended Projection Principle (EPP)*, modeled after Carnie (2021), is a constraint that states finite (Verb λ) nodes—verbal functions marked for grammatical tense—will activate the specifier algorithm. This means the function continues to project the root node, taking scope over the whole derivation as it had in the I-Phase, although linguistic adornment means the variables of the function have transformed to (Nom, Acc). This refers to *Nominative* and *Accusative* and denotes that the verb requires nodes respectively marked as its grammatical subject and object; this is known as the *transitivity* of the verb function.

The terminal node for the concept of <Jim> has transformed into the word *Jim* and moves into the vacant specifier position created by the EPP. This movement occurs because the node is adorned with (Nom) and is attracted to the first vacant position that can satisfy the variable requirements of the verbal function; see Radford (2016) and Carnie (2021) for evidence for such leftward movement of subjects around finite verbs during syntactic computation. The word *Ann*, denoting the concept <Ann>, integrates as a complement to the verbal function, satisfying the (Acc) variable requirement. This S-Phase derivation has re-rendered the initial I-Phase derivation into the syntactic structure for a clause in which a verbal function *kissed* takes *Jim* as its subject and *Ann* as its object.

DST incorporates the *Phase Impenetrability Condition* (PIC) that states computation within one phase cannot concurrently influence operations in an already-computed phase (Chomsky, 1995). Importantly, though, I-to-S Phase transition in DST subsumes the "vP" and "CP" phases proposed in Minimalist Theory (Chomsky et al., 2023). The leftward movement of subjects in language discussed above captures what Chomskyans call the "vP-Phase" and the same properties are found in I-to-S phase transition but also cover the analogs in other neurocognitive modalities. Meanwhile, phase transition is computed per-proposition in DST whereby representations that require multiple propositions will undergo a separate transition for each. This is viewed to be both a "chunking" working-memory resource constraint (Thalmann et al., 2019), as well as the optimal computation scope for the process λ functions in both the I and S Phases. This corresponds to the Chomskyan "CP-Phase."

Such parsimony results from the co-evolution of interactional representational and processing systems in which they shaped each other (see also Greco et al., 2023); the deep structural algorithms can only be instantiated with the processing systems, and the processing systems were only needed for much simpler genetically preprogrammed functions prior to the emergence of prototypical deep structure. The consequence is the *successive-cyclic* transmission of information between the chunked propositions in any neurocognitive modality involving multi-propositional structures. Chomskyans interpret this to be trace-copies of information being transmitted across CP-Phase boundaries in language (Carnie, 2021; Chomsky, 1995), and experimental evidence has been reported of successive-cyclical neuropsychological activations of phase-internal information during the time-locked processing of CP-Phase boundary segments (Boxell, 2012, 2014). Thus, it is possible that with a precise formulation of the deep structural representation geometry and a calculation of the available processing resources, neurocognition could be calculated for each phase:

$$\text{Neurocognition} = \frac{\text{D-Structure Representation}}{\text{Processing Resources}}$$

While the pure meaning computations of the I-Phase, or at least a prototypical version of it, are an older capacity that exists across mammalian species (Heyes & Huber, 2000), the more modern S-Phase is a set of human-specific and domain-specific computations. Even after phase transition, I-Phase level computation continues to be *independently* possible after the transition, in-keeping with the PIC. While the actual purpose of the S-Phase is to prepare a deep structure for potential further processing resulting in high-resolution consciousness, as will be discussed below, the existence of post-transition I-Phase level computations has two consequences: (1) some aspects of combinatorial meaning are modality-specific (i.e., expressed in one modality but not in others); (2) even after a deep structure has been S-Phase coded in preparation for potential consciousness, combinatorial meaning can still be computed within the I-Phase that will not become conscious.

Any given moment in a person's life requires representation of all the ambient data in the environment, as well as the generation of mental states that will produce all the needed outputs. Hundreds or thousands of I- and S-Phase deep structures are computed in synchrony to perceive each detail of the manifold stimuli in the environment, to respond to the range of environmental stimuli, and to retrieve relevant k-lines, all while also generating novel structures corresponding to new ideas.

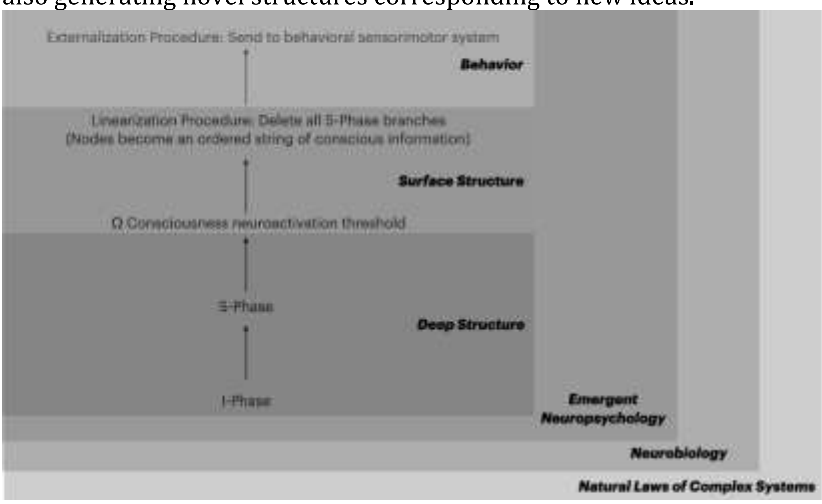


Figure 2. Deep Structure Theory: General Model

Linearization into Consciousness

Given the vast quantity of deep structures computed, they mostly remain *deep*—which is to say unconscious—or else the mind would descend into a state of "white noise." However, on occasion, one or two deep structures undergo a further transition as described in Figure 2. A deep structure that reaches a threshold level of neurological activation Ω will become self-aware, or conscious (Kang et al., 2017; Schurger et al., 2021; Soon et al., 2008). Interestingly, Ω seems to be related to the level of spreading activation across the whole neocortex, which speaks to the highly distributed information sources involved in a deep structural computation and reflects the imaging and modeling that has observed neurobiological integration of constituents at different levels of hierarchical deep structural computation (Aliko et al., 2023; Desbordes et al., 2024; Ding et al., 2016; Murphy, 2024; Perich et al., 2020; Stanojević et al., 2023; Uddén et al., 2020; Zhang & Ding, 2017). Moreover, some findings are potentially consistent with dissociable yet distributed I-Phase and S-Phase type operations (Kazanina & Poeppel, 2023; Matchin, 2023). It may be possible to specify which features of deep structure determine arrival at Ω in detail, although that is beyond the scope of the present paper.

According to DST, crossing Ω activates the *Linearization Procedure*, which simply states that all the branches of the deep structure are now deleted, leaving just free terminal nodes. Instead of the three-dimensional branching web of nodes in a hierarchical deep structure, these nodes are now in linearized into a two-dimensional string, or *surface structure*, that activates a sequence of speech sounds, words, sentences, brush strokes, dance steps, equation terms, musical notes, or whatever. In short, it becomes the thought that flashes through a person's conscious mind. Note that because the Linearization Procedure is non-computational, it is consistent with the mathematical implicature expressed in Gödel's Theorem that consciousness should be non-computational if it represents a computational system's understanding of itself (Penrose, 1989).

The nature of linearization also speaks to the adaptive function of the S-Phase: the adornments in this phase prepare the original I-Phase information structure for a high-resolution linearization of the terminal nodes within a given modality, such as language. In short, the S-Phase enables an imprint of the finer details of the I-Phase structure and its corresponding meaning to be conveyed in the conscious linearization mental state. The basic surface structure sequence itself is encoded by its underlying deep structural geometry using the *linear correspondence axiom* (Kayne, 1994). This states that if a node α is directly branch-attached to a higher node by a single branch, and this higher node also indirectly connects to a node β by more than one branch (this is known as an *antisymmetric c-command* relationship, see also Reinhart, 1976), then α (or whatever terminal node projects it) will precede β (or whatever terminal node projects it) in the linear string. For example, in Figure 1, it could be said that the node *M(Noun, Nom)*, which is projected by *T Jim (Noun, Nom),* antisymmetrically c-commands the node *T kissed (verb λ)* and the node *T Ann (Noun, Acc),* therefore the word *Jim* will precede the word *kissed* and the word *Ann* in the linear string of conscious linguistic thought; likewise, *T kissed (*verb *λ)* antisymmetrically c-commands *T Ann (Noun, Acc)*, therefore the word *kissed* will precede *Ann* in the linear string. Taken together, these antisymmetric c-command relationships yield the linear sequence *Jim kissed Ann* as a surface structure.

Note that while the linear correspondence axiom could work directly on the I-Phase, linearizing some abstract conceptualization with lower-resolution, the S-Phase modalities allow for more detail to be encoded. Prototypes of the I-Phase, and direct linearization thereof, likely capture the deep structural intelligence and consciousness observable in the learning, socialization, and empathetic folk "theory-of-mind" in non-human mammals (Heyes & Huber, 2000). The arrival of the S-Phase to mediate between the I-Phase and linearization is a later human-specific adaptation that advanced the mental representational and processing faculties. While aspects of human consciousness may involve direct linearization from the I-Phase, the absence of S-Phase mediation renders a cruder conveyance of abstract information into a conscious state such as in "tip-of-the-tongue" effects (Dell, 1995).

An important implication of DST is that it reduces the so-called *Hard Problem of Consciousness* (Chalmers, 1995), which concerns the nature of first-person phenomenological experience of the world (i.e., qualia), to a mere epiphenomenal biproduct of the unique string of linearizations that occurs in an individual. Varied environmental input, a varied epigenome, and the unbounded scope of innate deep structural algorithms each ensures that all individuals experience an utterly unique string of linearizations throughout their life-course development. Put more simply, consciousness is a string of ephemeral fragmentary surface structure echoes of the more complex unconscious deep structures from which they are derived; a good description of the unconscious system therefore yields an explanation of consciousness for free, because the latter simply reflects parts of the former.

Given most of the evolution of mental faculties involved the genetic foundations of the manifold unconscious states, it is consistent for conscious functionality itself to appear as such a minor additive adaptation. While the Hard Problem turns out to be an intractable problem, DST instead resituates the focus for inquiry on the need to elucidate the structure of the unconscious. Although it is beyond the scope of the present paper to discuss in detail, the implication of consciousness being an epiphenomenal aberration of deep structure is that the function of consciousness is to extract and insert nodes from either the environment or through its mediation of k-line activations to find and fill empty nodes, called *information gaps* (IGs). Thus, as humans develop, they will have an expanding repertoire of completed k-lines (i.e., without IGs) that will increase their capacity for neurocognition that can be accomplished without consciousness at all. It is probably no coincidence that the filter constraints discussed earlier for k-line activation (saliency, recency, and frequency) may also apply to consciousness, with IGs deriving a particular subtype of saliency.

Externalization

Finally, conscious linearized mental states can be translated into a sequence of specific basic sensorimotor actions for which there is a genetically preprogramed analog menu of actions for the speech articulators, the musculoskeletal system, limbs, bodily organs, and so forth, from which different corresponding combinations are selected (Inagaki et al., 2022; Zimnik & Churchland, 2021). This produces externalizations of thought, known as *behavior*. Meanwhile, *perception* is the same system as described, but running in reverse. This means phase transition can occur in either direction and, as such, not only can I-Phase conceptual deep structures formulate S-Phase structures, but modality-specific S-Phase structures can also impact the underlying I-Phase conceptualization. This would allow, for instance, for conceptualization to underpin language, but also for aspects of language to impact conceptualization (Boxell, 2016, 2025).

Quantum Electrodynamics

Piattelli-Palmarini and Vitiello (2017) demonstrate a mathematical isomorphism between adaptations of the deep structural algorithms, as defined using a combination of Chomskyan X-bar and Minimalist theory (Chomsky, 1986, 1995), and the equations of quantum field theory (QFT). Interestingly, the features that these authors adapted from the two forms of Chomskyan theory are all consistent with adaptations that are incorporated into DST for theory-internal reasons, meaning that the isomorphism with QFT transitively applies to DST and, in places, with even greater optimization. Such consistency with fundamental natural systems offers unprecedented parsimony and thus support for the DST paradigm as an account of neuropsychology. More specifically, the isomorphic features of DST and QFT are as follows.

First, it is X-bar deep structural geometry that is consistent with the quantum isomorphism described by Piattelli-Palmarini and Vitiello (2017). Notably, the DST algorithms presented in (1)-(6) are adapted from these older X-bar forms (Chomsky, 1986, 1970), rather than their more recently revised Minimalist equivalent (Chomsky et al., 2023). DST does this because X-bar computes its hierarchical representations from top-to-bottom and thus yields linearization sequences that are consistent with the linear processing time sequence. Meanwhile, Minimalism computes bottom-to-top, which yields inconsistent linearization sequences for processing. Such divergence with the latter Chomskyan approach occurs because Chomskyan linguistics assumes representation is the object of inquiry in a vacuum (Chomsky, 1986B), while DST posits that all mental faculties are representational and processing systems that co-evolved interactively, as discussed earlier. DST also adopts the X-bar algorithms because they directly capture the differing geometric relationships and corresponding observable behaviors between complement, adjunct, and specifier constituents. This gives X-bar, and by extension DST, greater explanatory adequacy because such distinctions are implicitly assumed without any formalism in Minimalism (Chomsky et al., 2023).

Second, Piattelli-Palmarini and Vitiello (2017) incorporated Chomskyan phase-analysis and the PIC from Minimalism (Chomsky, 1995). While Minimalism takes phases and the PIC to be representational constraints in the language faculty, the present paper outlined above how DST subsumes them under per-proposition I-to-S phase transitions as part of co-evolved representational and processing mechanisms. While they serve a radically different function in DST, phase transitions occur at essentially the same structural locations as proposed in Minimalism (broadly, at the boundary of a proposition), and thus account for the same representational facts. Moreover, DST allows phase-internal computations to continue in the I-Phase post phase transition without violating the PIC; this replicates the effects of linguistic Logical Form in Chomsky (1995) on which Piattelli-Palmarini and Vitiello (2017) rely in their isomorphism.

Third, deep structural algorithms produce bare structures consisting of abstract variables with more specific node labels added in the S-Phase, which Piattelli-Palmarini and Vitiello (2017) call a Labeling Algorithm. As such, the adornment features in the S-Phase are directly isomorphic with their Labeling Algorithm. Relatedly, *fourth*, the connection between deep structural computation and combinatorial meaning is inherent to the QFT isomorphism; notably, the more general conceptual I-Phase and the modality-specific S-Phase parameterization of combinatorial meaning arguably makes DST more consistent than the language-specific Chomskyan forms.

Finally, *fifth*, as terminal nodes are re-organized following a phase transition, DST postulates that *silent copies* remain in their original position in the prior phase. Indeed, unconscious reactivations of silent copies have been demonstrated empirically to affect processing (Boxell, 2012, 2014; Boxell & Felser, 2017; Boxell et al., 2017; Jessen et al., 2017). While Figure 1 has been oversimplified for exposition, a fuller derivation would show silent copies of all the I-Phase nodes in the S-Phase, still in their original I-Phase positions, but now overlaid alongside their S-Phase counterparts. This means that while S-Phase *Jim (Noun, Nom)* is higher in the computation than the position for *kissed (Verb λ)* and its silent copy *kiss (*λ) *[+PAST]*, there is also a silent copy of I-Phase *<Jim> (Agent)* that remains lower in the computation as well. The presence of silent copies is part of the QFT isomorphism (Piattelli-Palmarini & Vitiello, 2017).

As has been known since Planck (1900), Einstein (1905), and Bohr (1913), the constraints of time and space presuppose mass and gravity such that particles, photons, waves, and such exhibit quantum properties. These properties include *superposition* and *entanglement*, wherein all possible states in all possible spaces and times co-exist as wavefunctions until the collapse into a single steady-state that is associated with observation. Given that deep structures are massless electromagnetic oscillations, their quantizable nature is entirely consistent with current conceptions of QFT. Indeed, Piattelli-Palmarini and Vitiello (2017) note that their QFT isomorphism picks out neurological dynamic complex systems features and that "it is remarkable that the brain functional activity also shows self-similar features related to coherent amplitude and phase modulated neuronal oscillatory patterns," even going on to say the Chomskyan version of the algorithms with respect to the language faculty "might be the manifestation of a quite general phenomenon, deeply rooted in the very same brain physiological activity," (p.11).

While it has previously been suggested that consciousness may be a quantum phenomenon, perhaps related to the function of neuronal microtubules (Hameroff, 2022; Hameroff & Penrose, 1996, 2014; Penrose, 1989), DST implies that it is the computation of *unconscious* deep structural information processing that collapses an electromagnetic wavefunction out of a quantum field and into a steady state. Consciousness is reduced to the more superficial neuropsychological linearization procedure discussed above and is therefore more remote from the quantum properties of the underlying deep structure. While the mere existence of *quantum deep structure* (qDS) appears congruent with what is presently understood, it raises many profound frontier questions about the nature of the human mind that are beyond present methodological access and thus beyond meaningful speculation. Nonetheless, the exceptional level of parsimony between mental states and fundamental physics is itself highly encouraging support for the DST formulation.

Mediating The Mind and Biology

DST likewise provides parsimony between neuropsychology and other biological systems. While discussion of the link between matter and mental states dates back to the antiquarian philosophers, DST provides clear mediation between mind and body. Put simply, the neocortex generates and compiles emergent electromagnetic oscillations that encode abstract deep structures *and* it directly cross-talks at the cellular level with neurochemical and electrophysiological transmission to the general sympathetic and parasympathetic nervous systems, the immunological system, and the endocrine system (Hu et al., 2020; Pinho-Ribeiro et al., 2017; Stanton et al., 2023). As such, psycho-neuro-endoimmunological effects can find an explanatory neuropsychological mechanism in DST; for example, *visual perception* of pictures of pathogens inducing elevated proinflammatory cytokine interleukin-6 from white blood cells (Schaller et al., 2010), or memory of an immunosuppressant inducing reduction in white blood cell counts (Ader & Cohen, 1975). The well-known relationship between emotional distress and musculoskeletal tension similarly relates neocortical transmission to the general nervous system, inducing somatoform conditions (Pinho-Ribeiro et al., 2017; Rashbaum & Sarno, 2003; Stanton et al., 2023).

Bacterial, viral, fungal, and other microbiological entities are all known to have psychological effects along the microbiome-gut-brain axis (Ochoa et al., 2024; Prinsloo & Lyle, 2015), including dietary effects. In essence, these organisms' metabolites affect neurotransmitter compositions around the body that in turn disturb the connectonomics, and therefore the emergent deep structures, on arrival in the brain. Finally, gene-environment interactions, including gene-microbe crosstalk, produce molecular processes involving DNA (de-)methylation, histone modification, and noncoding RNA sequences that express or suppress genetic traits affecting an individual's phenotypic neurotransmitter and receptor molecule synthesis (Arden, 2019; del Val et al., 2024; Goriounova & Mansvelder, 2019; Roth, 2012; Stanton et al., 2023). As discussed above, while genetics provides an overall template for neural structure (Toga & Thompson, 2005), specific neural networking depends on cellular transmission, and thus environmental stimuli, over time (Seung, 2012).

Future Directions

Through the formulation of specific testable analyses, the DST framework facilitates future theoretical and empirical neuropsychology research questions across the full spectrum of principles governing mental activity. DST also has potential applications in theorizing and validating mechanisms of learning and change across different approaches to psychotherapy, education, organizational leadership, and neuro-symbolic artificial intelligence, among others. Not only may the deep structural paradigm explain existing efficacy in such domains, but also how to augment it with precise configurations that are aligned with mental functioning (Boxell, 2025).

Conclusion

Theoretical, methodological, and neurocognitive modalities-of-interest represent arbitrary and non-mutually exclusive siloes in cognitive neuropsychology. The current paper presents a synthetic unified model of neurocognition called Deep Structure Theory (DST) in which algorithmic mental states are grounded in the compiling of electromagnetic oscillations across dynamic complex systems of neural circuits. This provides a general model of emergent neuropsychology with core computational mechanisms across all its faculties. DST is situated within meta-modernist epistemology and continues a long arch of historical developments in mental state theory. The formal features of the representational deep structural algorithms and their application across all neurocognitive computations are presented, including their memory encoding mechanism, the formulation of consciousness, and interaction with processing systems. Finally, the relationships within and between deep structural computation, biological systems, and quantum electrodynamics are established, thereby demonstrating the unifying capacity and explanatory adequacy of the DST paradigm.

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